JOHNSTON'S HAND-BOOK

TO THE

CELESTIAL GLOBE

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ESTABLISHED AYE READY READY 1825

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INTRODUCTION.

This Handbook is specially intended to accompany Johnston's Celestial Globes. The Celestial Globe does not represent the true movements of the heavenly bodies. As far as power of using and understanding the Globe is concerned, it matters not whether the Sun moves round the Earth or the Earth round the Sun. The Globe enables us to imitate the *appearances* of the Heavens without entering upon the reasons why the appearances are what they are, and, when rotated, it is of great assistance in enabling us to study the diurnal phenomena. Professor Young states that "the study of the celestial sphere and its circles is greatly aided by the use of a globe or armillary sphere; indeed, without some such apparatus it is rather difficult to get clear ideas upon the subject."

There are three distinct steps in the attainment of a sound knowledge of Astronomy. The first is to get an accurate notion of what appears in the Heavens, and to know well the apparent positions and changes of the heavenly bodies; and the second is to apply that knowledge to a practical use in the actual prediction of the appearance of the Heavens at any particular time. These two acquirements may be got from an intelligent use of the Globe; but the third step, namely, the deductions of the *real* motions from the *apparent* ones can be better obtained from the study of a good textbook on Astronomy. The viewing is always supposed to be done from the centre of the Globe. We may imagine the Globe transparent, and the eye placed at the centre of the hollow sphere upon which are drawn the circles and a map of the stars: then will the heavenly bodies appear on the Globe in their true positions relatively to each other. When the Globe is rotated from east to west, the Stars will appear to rise, cross the meridian, and sink in the west, exactly in a similar

manner as we see them do in the Heavens. In the hands of an expert student many problems on Astronomy and Navigation of great importance may be readily solved.

It is very necessary that the observer should have an Almanac giving the data necessary for determining the positions on the Globe of the Sun, Moon, Planets, and Stars. He should also make himself perfectly familiar with the different Kinds of Time. A brass Quadrant will also be found useful for ascertaining the Altitude and Azimuth of a heavenly body at any time.

Only the most important problems on the Globe—those involving the fundamental principles of the matter—have been solved, and in a few cases the results are given in *sidereal* instead of *mean* time, but these will be found sufficiently accurate for all ordinary purposes.

The explanations and instructions are purposely given in simple language for the benefit of those who may not yet be quite familiar with technical astronomical terms.

THE CELESTIAL GLOBE.

Celestial Globe.—The Celestial Globe is a ball on which are drawn a number of circles of the celestial sphere, and also a map representing the stars in their true positions as seen from the centre of the sphere. The globe is mounted in a framework which represents the horizon and meridian. The compass fixed at the foot of the stand is used for placing the brass meridian into the plane of the observer's meridian, but to do this the variation of the compass, if any, at the observer's station must be allowed for.

Axis and Poles.—The Axis of rotation is an imaginary line joining the north and south celestial poles. If an imaginary line be drawn joining the north and south poles of the earth, and extended indefinitely both ways, the two opposite points where it meets the celestial sphere are called the North and South Celestial Poles. The Terrestrial and Celestial Globes have therefore a common centre and axis of rotation, but the rotation (apparent) of the latter is from east to west.

Horizon Circle.—The Horizon is usually a wooden ring 3 or 4 inches wide surrounding the globe, and is directly supported by the pedestal. It carries upon its upper surface a number of concentric circles :—

(1) **Amplitude.**—The innermost or Amplitude Circle is divided into four equal parts at the cardinal points (N.E.S.W.), and each of these into degrees. The amplitude of a star, etc., is reckoned in degrees from the east and west points towards the north and south.

(2) **Azimuth.**—The Azimuth Circle is divided in a similar manner to (1), but the azimuth is counted from the north and south points towards the east and west. Sometimes the

azimuth is read from the north point only, through the east and west to the south.

(3) **Compass.**—The Compass Circle is divided into thirty-two equal parts, similar to the mariner's compass, and shows the direction on the observer's horizon that the heavenly bodies rise and set.

(4) **Zodiacal Circle.**—The Zodiacal Circle is divided into twelve equal parts, called the Zodiacal Signs, and each sign divided again into degrees.

(5) **Sun's Longitude.**—The remaining circles mark the months and days in each month. Opposite each day will be seen the Sun's position in the different signs, or, in other words, it gives the Sun's longitude for each day of the year. For example, 20th March is opposite the beginning of Aries and the Sun's longitude 0° on that day. Again, the 23rd October is opposite the beginning of Scorpio and the longitude is 210°. The dates of the Sun's entering the different signs change slightly, owing to the length of the year not being an exact number of days.

Meridian Ring.—The Meridian is a circular ring of metal which carries the bearings of the axis on which the globe rotates. The graduated face of the ring is exactly in the same plane as the mathematical axis of the globe. This ring, which represents the meridian of the observer, fits into two notches in the horizon circle, and is held underneath the globe by a support with a clamp, which enables us to fix it securely in any desired position. The mathematical centre of the globe is thus in the plane of the meridian and also in the plane of the horizon. The ring is divided on one side into degrees and fractions of a degree, with zero at the equator and 90° at the poles, in one of the semicircles. This semicircle is used for ascertaining the meridian altitude of an object and also its declination, by bringing the object up to the graduated edge of the meridian and reading off the number of degrees it is north or south of the equator. The other semicircle is similarly divided, but the zero points are at the poles and 90° at the equator, and is used for setting the globe to the observer's latitude. For example, if the observer's latitude be 56° N., then the north celestial pole must be elevated 56° above the north horizon point; but if the latitude be 56° S., then the south pole is

raised 56° above the south horizon point. Observe that in doing this we are always placing the axis of the globe parallel to the earth's axis.

Hour- or Time-Circle.—The Hour- or Time-Circle is a brass circle with the north polar axis as centre, and is graduated into hours, quarters, and sometimes to five minutes. It may be turned round the axis with stiffish friction when setting it, but it is carried round along with the rotating globe. It is used in all problems involving time, and the settings and readings are always done on the graduated edge of the meridian. One rotation of the globe reads twenty-four hours (sidereal) on the circle.

Compass.—At the foot of the pedestal there is a Magnetic Compass, very similar to the mariner's compass. This is used for the purpose of placing the meridian ring into the plane of the observer's true meridian when the variation of the compass is known at his station. For example, if the variation is 16° W. of north, then the needle must be made to point 16° W. of north, and the meridian ring will be in the plane of the observer's meridian. It is not necessary to do this, as we may always *assume* the ring to be so placed.

Quadrant.—The Quadrant of Altitude is a flexible graduated slip of brass having a clamp at one end by which it can be fixed to the meridian ring, and is used for finding the altitude of a celestial body above the horizon, and also the angular distance between two objects on the sphere. It is generally graduated into 108°, and is numbered upwards from 0° to 90° and downwards from 0° to 18°. The lower divisions are used for calculating the length of twilight.

Surface of the Globe.—The principal circles on the surface of the globe are: (1) The Equator, (2) the Declination Circles, (3) the Hour-Circles, and (4) the Ecliptic.

Equator.—The Celestial Equator or Equinoctial is a great circle of the celestial sphere, drawn half way between the poles and everywhere 90° from each of them. If a plane be passed through the earth's equator, and extended indefinitely, it will trace out this great circle on the celestial sphere. The circle is divided into degrees numbered from the First Point of Aries. The globe makes one rotation in twenty-four hours (sidereal), and therefore turns through 15° in one hour, 15′ in one minute, and 15″ in one second, so that this circle may be read either

in *time* units, or in *degrees*. The right ascension of an object is read off on this circle usually in *time*. For example, if the right ascension of Sirius be wanted, we bring Sirius to the graduated edge of the meridian circle and read off on the equator its right ascension, namely, 6 h. 41 m., and its declination on the meridian circle, 16° 35′ S. Those two co-ordinates, namely, right ascension and declination, determine the position of an object on the celestial sphere.

Declination Circles.—Declination Circles are small circles drawn parallel to the equator, usually 10° apart, and correspond to the parallels of latitude on the earth's surface.

Hour-Circles.—Hour-Circles are great circles, usually twenty-four in number, passing through the poles, like the meridians on the earth, and are therefore perpendicular to the equator and divide it into twenty-four equal parts, each representing one hour or fifteen degrees.

Ecliptic.—The Ecliptic is a great circle cutting the celestial equator at an angle of $23\frac{1}{2}°$. It represents the apparent path of the Sun traced out on the celestial sphere during the year, and is divided into degrees, numbered from the First Point of Aries. It is also divided into twelve equal parts of 30° each, called the Twelve Signs of the Zodiac. The Sun's longitude is read off on this circle in degrees, beginning at the Vernal Equinox—thus the Sun's longitude for 3rd December 1911 is 250° 13′.

Poles of the Ecliptic.—The Poles of the Ecliptic are the points 90° distant from the ecliptic. The position of the north ecliptic pole is on the solsticial colure, $23\frac{1}{2}°$ from the pole of rotation, in declination $66\frac{1}{2}°$ N. and right ascension 18 hours.

Celestial Latitude.—Celestial Latitude is the angular distance of a heavenly body north or south of the ecliptic.

Celestial Longitude.—Celestial Longitude is the arc of the ecliptic intercepted between the Vernal Equinox and the foot of a circle drawn from the pole of the ecliptic to the ecliptic through the object. On some celestial globes circles from the poles of the ecliptic perpendicular to the ecliptic (ecliptic meridians) are drawn instead of hour-circles. Distinguish clearly between terrestrial and celestial longitude and latitude, as they signify very different things.

Co-ordinates.—There are therefore three ways of determining the position of an object on the Celestial Globe, namely:—

(1) When the Right Ascension and Declination are known.
(2) When the Altitude and Azimuth are known.
(3) When the Longitude and Latitude are known.

Stars.—On the surface of the globe are plotted the correct positions of the Stars taken from the most reliable sources. Names are attached to all the principal stars, while others are denoted by letters (Greek or Roman) or numbers only.

Constellations.—There are also given the outlines of the Constellations and the old constellation figures.

Planets.—The positions of the Sun, Moon and Planets are not represented on the globe, since they change their place on the celestial sphere from day to day, but their places may be obtained from the *Nautical Almanac.*

DEFINITIONS.

Aries.—The First Point of Aries is the point where the Sun crosses from the south to the north side of the equator, and is the starting point for reckoning longitude and right ascension.

Altitude.—The Altitude of a heavenly body is its angular elevation above the horizon measured on a vertical circle from the zenith through the object.

Amplitude.—The Amplitude of a body is its angular distance from the east or west points of the horizon.

Apparent Noon.—Apparent Noon is the time when the true Sun is on the meridian, as opposed to Mean Noon when the *mean Sun* (which does not appear) is on the meridian.

Azimuth.—Azimuth is the arc of the horizon intersected between the north point and the foot of a vertical circle drawn from the zenith through the object.

Circles.—Great Circles have the centre of the globe as their centres; all others are Small Circles.

Circumpolar Stars.—Circumpolar Stars are those that never set in the observer's latitude. For example, in latitude

56° N. all stars having a declination greater than 34° N. are circumpolar.

Colures.—The hour-circles drawn from the poles of rotation through the equinoctial and solsticial points are called the Equinoctial and Solsticial Colures. They correspond to the 0, 6, 12, and 18 hours of right ascension.

Declination.—The Declination of a star, etc., is its angular distance north or south of the equator—$+$ if north and $-$ if south.

Equation of Time.—The difference between *apparent time* and *mean time* is called the Equation of Time. The *Nautical Almanac* gives the Equation of Time for each day of the year. (*See* Table II.)

Right Ascension.—Right Ascension is the arc of the celestial equator intercepted between the Vernal Equinox and the point where the star's hour-circle cuts the equator. It is reckoned always *eastward* from the equinox completely around the circle, and may be expressed either in degrees or time units.

Solstices.—The Summer and Winter Solstices are points on the ecliptic midway between the two equinoxes where the Sun attains its maximum declination of $+23\frac{1}{2}°$ and $-23\frac{1}{2}°$ respectively.

Time. (a) *Sidereal.*—The Sidereal Day is the interval of time between two successive transits of a star over a given meridian, and begins when the Vernal Equinox is on the observer's meridian. It is divided into twenty-four sidereal hours, but it is nearly four minutes shorter than the *mean time* day.

(b) *Solar.*—A Solar Day is the interval of time between two successive transits of the Sun over the meridian. When the Sun's centre is on the meridian it is *apparent noon.* The solar days are of unequal lengths.

(c) *Mean.*—A Mean Time or Civil Day is the interval of time between two successive transits of the *mean Sun* over the meridian. This is the time kept by the watch.

(d) *Astronomical.*—The Astronomical Mean Time Day begins at *mean noon*, the Civil Day twelve hours earlier at midnight. Astronomical Mean Time is reckoned continuously through the whole twenty-four hours instead of being counted in two series of twelve hours each: Thus 9 A.M., Tuesday, 26th

September 1911, *civil* reckoning is 21 o'clock, Monday, 25th September, by *astronomical* reckoning.

(e) *Local and Standard.*—A sidereal clock should keep Local Sidereal Time, but if the observer keeps Standard Mean Time and he is not placed on the *standard meridian*, then, in all his calculations involving time, he must allow for his difference of longitude—+ if west and − if east. For example, if the Sun is on the meridian of Greenwich at 12 h. 10 m. P.M., then it will not be on the meridian of a station 3° W. till 12 minutes later, viz., 12 h. 22 m. P.M., G.M.T.

The Sidereal Day = 23 h. 56 m. 4 s. of mean solar time.

The Mean Solar Day = 24 h. 3 m. 56 s. of sidereal time.

Twilight.—Evening Twilight begins at sunset and is supposed to end when the Sun is 18° below the horizon or when stars of the sixth magnitude become visible near the zenith. Morning Twilight begins when the Sun is again 18° below the horizon and ends at sunrise.

Vertical Circles.—Vertical Circles are great circles drawn from the zenith at right angles to the horizon, and therefore passing through the nadir also. Their number is indefinite.

Celestial Meridian.—The vertical circle passing north and south through the pole is the Celestial Meridian, and is the circle traced on the celestial sphere by the plane of the terrestrial meridian upon which the observer is situated.

Prime Vertical.—The vertical circle at right angles to the meridian and passing through the east and west points of the horizon is called the Prime Vertical.

Zenith and Nadir.—The Zenith is that point in the heavens directly over head, and the Nadir the point directly under foot in the invisible part of the celestial sphere.

Zodiac.—The Zodiac is a belt of 16° wide (8° on each side of the ecliptic). The Moon and all the principal planets keep within this belt. The names of the Twelve Signs of the Zodiac are also names given to twelve constellations in the heavens, and at one time the signs and constellations occupied the same positions, but owing to the precession of the equinoxes each sign has changed its position about 30° west of its corresponding constellation. The Sun's place in the ecliptic is usually given in degrees of longitude.

CONSTELLATIONS.

The stars are grouped into so-called "Constellations." Their names are, for the most part, drawn from the Greek and Roman mythology, many of them being connected with the Argonautic Expedition.

Of the sixty-seven constellations now generally recognised forty-eight have come down from Ptolemy. The others have been added since about 1600 by later astronomers, mainly to provide for the stars near the southern pole. Argelander is now generally accepted as the authority for the Northern Constellations, and Gould for the Southern. It is a matter of great convenience and of real interest to an intelligent person to be acquainted with the principal constellations, and to be able to recognise the brighter stars—from fifty to one hundred in number—and this knowledge is easily obtained by studying the heavens in connection with a good celestial globe.

There are different methods of designating individual stars. (*a*) About sixty of the brighter stars have names in more or less common use. Some are of Greek or Latin origin—for example, Capella, Sirius, Procyon, etc.—and others have Arabic names—Vega, Aldebaran, Altair, etc. (*b*) In 1603 Bayer adopted the plan of designating stars in a constellation by the letters of the Greek alphabet. The letters were *generally* applied in order of brightness, α being the brightest in a constellation and β the next brightest. If the naked-eye stars in a constellation were numerous so as to exhaust the letters of the Greek alphabet then Roman letters were next used, and, if necessary, numbers were next employed to complete the list. The star nomenclature used in connection with Johnston's Celestial Globes is mainly that adopted in the *British Association Catalogue of Stars*, which gives the positions of 8377 stars.

The Nebulæ are not inserted because of overcrowding the globe, and also because they are nearly all invisible to the naked eye. To follow these faint patches of light the observer must employ a good telescope, and have a catalogue giving their true positions. Stars are usually described by the genitive case: θ Virginis, θ of Virgo; 10 Argûs, 10 of Argo; β Orionis, β of Orion, are instances.

LIST OF CONSTELLATIONS IN ORDER OF RIGHT ASCENSION.

Andromeda
Cassiopéia
Pégasus
Octans
Cetus
Toucánus
Pisces
Hydrus
Phœnix
Sculptor
Ursa Minor
Erídanus
Aries
Triangulum
Fornax
Perseus
Horologium
Taurus
Reticulum
Dorádo
Orion
Auriga
Camelopardalis
Lépus
Columba
Gemini
Canis Major
Argo
Pictor
Cepheus
Volans
Carina
Canis Minor
Monoceros
Octans
Cancer
Puppis
Ursa Major
Malus
Hydra
Lynx
Leo
Vela
Sextans
Antilia
Crater
Draco
Centaúrus
Virgo
Corvus
Crux
Chamæleon
Musca
Coma Berenices
Canes Venatici
Boötes
Libra
Circinus
Lupus
Ursa Minor
Triangulum Australe
Corona Borealis
Serpens
Scorpio
Ophiuchus
Norma
Hercules
Ara
Pavo
Sagittarius
Telescopium
Corona Australis
Lyra
Aquila
Vulpecula
Cygnus
Capricornus
Equuleus
Delphinus
Indus
Lacerta
Aquarius
Piscis Australis
Microscopium
Grus

SIGNS OF THE ZODIAC.

And Approximate Dates on which the Sun enters each Sign.

Spring	♈ Aries (The Ram) 0° – 30°, 21st March.
	♉ Taurus (The Bull) 30° – 60°, 20th April.
	♊ Gemini (The Twins) 60° – 90°, 21st May.
Summer	♋ Cancer (The Crab) 90° – 120°, 21st June.
	♌ Leo (The Lion) 120° – 150°, 23rd July.
	♍ Virgo (The Virgin) 150° – 180°, 23rd August.
Autumn	♎ Libra (The Balance) 180° – 210°, 22nd September.
	♏ Scorpio (The Scorpion) 210° – 240°, 23rd October.
	♐ Sagittarius (The Archer) 240° – 270°, 22nd November.
Winter	♑ Capricornus (The Goat) 270° – 300°, 21st December.
	♒ Aquarius (The Water Bearer) 300° – 330°, 20th January.
	♓ Pisces (The Fishes) 330° – 360°, 19th February.

TO RECTIFY THE GLOBE.

To rectify the globe, that is, to set it so as to show the appearance of the heavens at any given time :—

(1) It is sometimes convenient to place the meridian ring into the plane of the observer's meridian. This is done by the aid of the compass at the foot of the stand, but the variation of the compass must be allowed for.

(2) If in north latitude, elevate the north pole of the globe to an angle equal to the latitude of the place, and clamp the ring firmly.

(3) On the horizon ring (or *N. A.*) look up the day of the month, and opposite it will be found the Sun's longitude for that day.

(4) On the surface of the globe (on the ecliptic) find the corresponding degree of longitude. Mark its position with a piece of moist white paper, and bring this mark to the graduated edge of the meridian ring.

(5) Keeping the globe tightly in this position, turn the hour-circle at the pole until it shows XII. on the graduated side of the meridian ring. The globe is now set to *local apparent noon* for the day in question.

(6) From Table II. find the *equation of time* for the date required, and add to or subtract from (as the case may be) XII. this amount. Turn the hour-circle the same amount, and this gives *local mean time* at *apparent noon.*

(7) If *standard time* be kept, such as Greenwich mean time, then the difference of longitude must be taken into account (+ if west and − if east), and the hour-circle again corrected for the longitude. This gives *standard mean time* at *apparent noon.*

(8) Finally, turn the globe until the hour-circle reads off at the graduated edge of the meridian ring the hour proposed in the example, and all above the horizon ring shows the appearance of the heavens for that hour. (One rotation of the globe = 24 sidereal hours.)

Moon and Planets' Positions. – The positions of the Moon and Planets are not represented on the globe, but these may be got from the *Nautical Almanac* for any day of the year, and their places marked on the globe with a piece of white paper and wiped off again when finished with the problem.

South Latitude.—If the observer's station is south latitude, then the south pole is elevated to the latitude, but it will be found more convenient to have the hour-circle attached to the south pole.

If the observer is situated at the earth's equator, the poles will be in his horizon, and the celestial equator will be a vertical circle, coinciding with the prime vertical. All heavenly bodies will *rise and set vertically*, so that they will be twelve hours above and twelve hours below the horizon.

If the observer is at the pole of the earth, or latitude 90°, the celestial pole will be at his zenith and the equator will coincide with the horizon If at the north pole, all the stars north of the celestial equator will remain permanently above the horizon, sailing round the sky on parallels of altitude. The Sun will thus be visible for about six months in the year and the Moon about a fortnight each month. Here the definitions of meridian and azimuth break down, since at that point the zenith coincides with the pole. Facing which direction he will, he is still looking directly south.

PROBLEMS SOLVED BY THE CELESTIAL GLOBE.

Problem 1.—To find the Sun's position in the Ecliptic for any given day.

(1) What is the Sun's longitude on the 10th May?
Look to the horizon circle for the date 10th May, and opposite it is 19° Taurus: therefore the Sun's longitude is 49°.

(2) What is the Sun's longitude on the 29th August?
Answer.—155°.

Problem 2—To find the date when the Sun has a particular longitude.

(1) On what day is the Sun's longitude 209°?
This is 29° of Libra, and opposite it on the horizon circle is the 23rd October.

(2) On what day is the Sun in 13° of Capricornus?
Answer.—4th January.

Problem 3.—To find the Sun's declination for any given day.

(1) Find the Sun's declination on the 30th January.
On the 30th January the Sun's longitude is 310° (Problem 1). Bring this mark to the graduated edge of the meridian, and this circle reads 18° S.

(2) Find the Sun's declination on the 11th June.
Answer.—23° N.

Problem 4.—To find the dates when the Sun has a particular declination.

(1) On what days is the Sun's declination 22° N.?
Turn the globe until a point on the Ecliptic reads 22° N. on the meridian circle, and this point reads long. 71° and 110°, which corresponds (Problem 2) to the 2nd June and 13th July respectively.

(2) On what days is the Sun's declination 22° S.?
Answer.—11th January and 3rd December.

Problem 5.—To find the Sun's meridian altitude at a given place on a given day.

(1) Find the Sun's meridian altitude at Edinburgh (lat. 55° 57′ N.) on the 25th April. 30+5

The Sun's position is 5° ♉ or 35° long. (Problem 1) on the 25th April. Rectify the globe, that is, elevate the North Pole 55° 57′ above the north horizon, and bring the Sun's position to the graduated edge of the meridian ring. Count the number of degrees from this point to the horizon, and this gives the meridian altitude 47°.

(2) Find the Sun's meridian altitude at New York (lat. 40° 42′ N.) on the 26th February.

Answer.—40° 18′.

Problem 6.—To find the observer's latitude when the Sun's true meridian altitude and day of the month are given.

(1) On the 30th April the captain of a ship found the Sun's true meridian altitude to be 44° 30′ to the *south* of him. Find his latitude.

The Sun's longitude on the 30th April is 39° (Problem 1). Bring the Sun's position to the meridian, and elevate this mark 44° 30′ above the *south* horizon point, and the North Pole is 60° above the *north* horizon point. The latitude is therefore 60° N.

Note.—The altitude of the Pole is equal to the latitude of the place.

(2) On the 22nd December the Sun's true meridian altitude was found to be $10\frac{1}{2}$° to the south of the observer. Find his latitude.

Answer.—56° N.

Problem 7.—(1) An observer at sea found the Sun's true meridian altitude on the 26th February 1911 to be 49° to the *north* of him. Find his latitude.

Get the Sun's position for 26th February (Problem 1), and bring it to the meridian ring. Elevate the Sun's place 49° above the *north* point of the horizon, and the altitude of the South Pole above the *south* horizon point reads 50°. The latitude is therefore 50° S.

(2) On the 16th of March the Sun's true meridian altitude

was found to be 62° to the north of the observer. Find his latitude.

Answer.—30° S.

Problem 8.—Given the latitude, Sun's altitude, and day of the month: to find the hour of the day and the Sun's true bearing.

(1) At London on the 10th May 1911 the Sun's altitude was observed to be 40°: find the hour of the day and the Sun's true bearing.

Rectify the globe to $51\frac{1}{2}$° N., and mark the Sun's position for 10th May (Problem 1). Clamp the brass quadrant to meridian ring at $51\frac{1}{2}$° N. Bring the Sun's place to the meridian, and set the hour-circle to XII. Turn the globe and quadrant until the Sun's place reads 40° altitude on the quadrant, and the hour-circle will read 8 h. 53 m. for forenoon and 3 h. 7 m. for afternoon. The foot of the quadrant cuts the horizon circle in the E.SE. and W.SW. nearly, which are the Sun's true bearings at the above times respectively.

Note.—The above results are given in *apparent time.*

We have assumed that the Sun is on the meridian at noon. If *mean* or *watch time* be wanted, then the equation of time (3 m. 41 s.) must be subtracted from apparent noon, and the hour-circle set to 11 h. 56 m. 19 s. instead of XII. to give G.M.T. when the Sun's altitude was 40°.

(2) In latitude 56° N. on the 4th October 1911 the Sun's altitude was found to be 17°: find the apparent time and the Sun's true bearing or azimuth from the north.

Answer.—Time, 9 A.M. and 3 P.M.; Bearing, 130° 35′ from the north.

Problem 9.—Given the latitude and day of the month: to find the Sun's altitude and hour of the day when the Sun is due east or on the Prime Vertical.

(1) Find the Sun's altitude and when it is due east at London on the 10th May 1911.

Rectify the globe to $51\frac{1}{2}$° N., get the Sun's place on 10th May (Problem 1), and bring it to the meridian. Set the hour-circle to XII., and clamp the quadrant to $51\frac{1}{2}$° N. Bring the quadrant's graduated edge to the east horizon point, and turn the globe until the Sun's place is on the graduated edge

of the quadrant. The altitude reads $23\frac{1}{2}°$ and the hour-circle 7 A.M.

(2) Find the Sun's altitude, and when on the Prime Vertical in latitude 40° N. on the 2nd August 1911.

Answer.—Altitude, 27°; Time, 7 h. 32 m. A.M. (apparent time).

Problem 10.—To find the Sun's altitude and azimuth at a given place at any hour of a given day.

(1) Find the Sun's altitude and azimuth at London on the 8th September at 10 A.M. (apparent time).

Rectify the globe, clamp brass quadrant to $51\frac{1}{2}°$ N., mark the Sun's place for 8th September and bring this mark to the meridian. Set the hour-circle to XII. Turn the globe eastward 2 hours, and bring the graduated edge of the quadrant to coincide with the Sun's position. Read off the quadrant, and this gives the Sun's altitude 38°. Count the number of degrees on the horizon circle from the north point to the graduated edge of the quadrant, and this gives the Sun's azimuth 140° 45′.

(2) Find the Sun's altitude and azimuth in latitude 45° N. at 3 P.M. on 8th September 1911.

Answer.—Altitude, 38°; Azimuth, 121° from the north.

Problem 11.—Given the Sun's longitude: to find the apparent time of sunrise and sunset at a particular place.

(1) Given the longitude of the Sun 209°: find the local apparent time of sunrise and sunset in latitude 60° N.

Rectify the globe to 60° N. Find the Sun's place in the Ecliptic (Problem 1) and bring it to the meridian. Set the hour-circle to XII., and turn the globe until the Sun's place is on the horizon. The hour-circle reads 7 h. 12 m. A.M. and 4 h. 43 m. P.M., which are the times of sunrise and sunset respectively.

(2) The Sun's longitude on the 23rd October is 209°: find the apparent time of sunrise and sunset in latitude 30° N.

Answer.—Sunrise, 6 h. 26 m. A.M.; Sunset, 5 h. 34 m. P.M.

Problem 12.—Given the Sun's longitude 209° on the 23rd October: find the time (apparent) of sunrise and sunset in latitude 60° S.

Elevate the South Pole 60° above the south horizon point. Mark the Sun's place and bring it to the meridian. Set the hour-circle to XII., and turn the globe until the Sun's position is on the horizon. The hour-circle reads 4 h. 43 m. A.M. and 7 h. 17 m. P.M., the times of sunrise and sunset respectively.

(2) Find the apparent time of sunrise and sunset on the 23rd October in latitude 30° S.

Answer.—Sunrise, 5 h. 34 m. A.M.; Sunset, 6 h. 26 m. P.M.

Problem 13.—Given the Sun's longitude: find (1) the G.M.T. of sunrise and sunset, and (2) the length of the day and night at a particular place.

(1) Given the Sun's longitude (184°) on the 28th September 1911: find (1) the G.M.T. of sunrise and sunset, and (2) the length of the day and night at Edinburgh (lat. 55° 57′ N., long. 12 m. 43 s. W., equation of time − 9 m.).

On the 28th September the Sun is on the meridian of Greenwich 9 minutes *before* noon, therefore it will be on the meridian of Edinburgh 12 m. 43 s. later, namely, at 12 h. 3 m. 43 s. G.M.T. Rectify the globe, mark the Sun's place on the globe and bring this mark to the meridian. Set the time-circle to 12 h. 4 m., and turn the globe until the Sun's place is on the horizon. The time-circle reads 6 h. 10 m. A.M. and 5 h. 58 m. P.M., the G.M.T. of sunrise and sunset respectively. Again, from 6 h. 10 m. to 12 h. 4 m. is 5 h. 54 m., and double this amount gives 11 h. 48 m. = the length of the day, and 24 h. − 11 h. 48 m. = 12 h. 12 m. = the length of the night.

(2) Given the longitude of the Sun on the 12th July 1911 as 109°: find (1) the *apparent* and (2) the *local mean* time of sunrise and sunset at Edinburgh (equation of time + 5 m. 16 s.).

Note.—The Sun is on the meridian of Edinburgh at 12 h. 5 m. 16 s. *local mean time.*

Answer.—Apparent time of rising, 3 h. 28 m. A.M.;
Apparent time of setting, 8 h. 32 m. P.M.;
Local mean time of rising, 3 h. 33 m. A.M.;
Local mean time of setting, 8 h. 37 m. P.M.

(3) Given the R.A. 20 h. 40 m. and Dec. 18° 21′ S. of the Sun on the 28th January: find the *mean* time (1) of sunrise

and sunset, and (2) the length of the day and night at London (lat. $51\frac{1}{2}°$ N., long. 0°, equation of time +13 m.).

Answer.—7 h. 47 m. = time of sunrise;
4 h. 39 m. = time of sunset;
8 h. 52 m. = length of the day;
15 h. 8 m. = length of the night.

Problem 14.—To find the beginning, end, and duration of twilight at any given place on any given day.

Note.—Twilight begins at sunset and is supposed to end when the Sun is 18° below the horizon. It begins again when the Sun is 18° below the horizon and ends at sunrise.

(1) Find the beginning, end, and duration of evening and morning twilight at London on the 1st May 1910. (Lat. $51\frac{1}{2}°$, R.A. 2 h. 31 m., Dec. 14° 53′ N., Equation of time −3 m.)

Rectify the globe for $51\frac{1}{2}°$ N., bring R.A. 2 h. 31 m. (on the Equator) to the graduated edge of the meridian ring, and 14° 53′ N. read on the meridian gives the Sun's place for the 1st May. This gives by Problem 13 the time of sunset and sunrise as 7 h. 20 m. P.M. and 4 h. 35 m. A.M. respectively. Clamp the brass quadrant to $51\frac{1}{2}°$ N., bring the Sun's position to the west horizon, and set the hour-circle to 7 h. 20 m. Turn the globe and quadrant until the Sun's position reads 18° on the quadrant below the horizon. Read off the hour-circle, and this gives 9 h. 56 m., and 9 h. 56 m. − 7 h. 20 m. = 2 h. 36 m. is the length of twilight. Twilight begins again at 4 h. 35 m. − 2 h. 36 m. = 1 h. 59 m.,
therefore 7 h. 20 m. P.M. is the beginning of evening twilight,
and 9 h. 56 m. P.M. is the end of evening twilight;
1 h. 59 m. A.M. is the beginning of morning twilight,
and 4 h. 35 m. A.M. is the end of morning twilight;
and 2 h. 36 m. is the duration of morning and evening twilight.

(2) Find the beginning, end, and duration of evening twilight at London on the 6th August 1910. (Sun's R.A. 9 h. 2 m., Dec. 16° 53′ N., Equation of time + 6 m.)

Answer.—Sunset or beginning of twilight = 7 h. 38 m. P.M.
End of twilight = 10 h. 16 m. P.M.
Duration of twilight = 2 h. 38 m.

Problem 15.—To find between what dates does twilight last all through the night in a given latitude.

Note.—In this case the Sun when due north must not be more than 18° below the horizon.

(1) In the latitude of Glasgow (55° 53′ N.) find between what dates there is no real darkness.

The maximum distance from the North Pole to the Sun's position when due north is $55° 53' + 18° = 73° 53'$. From the North Pole to the Equator is 90°, therefore the Sun's minimum Dec. N. must be $90° - 73° 53' = 16° 7'$. Elevate the North Pole to the latitude, namely, 55° 53′ N., and turn the globe until a point in the Ecliptic reads 16° 7′ N. on the meridian circle. There will be found two such points which by Problem 2 (or *N.A.*) correspond to the 6th May and 9th August. There is therefore no real darkness between those two dates.

(2) Between what dates is there no real darkness in latitude 60° N.?

Answer.—Between the 23rd April and 22nd August.

(3) In what latitudes does twilight continue all through the night only once in the year? (Sun's maximum Dec. $23\frac{1}{2}°$ N. and $23\frac{1}{2}°$ S.)

Answer.—Lat. $48\frac{1}{2}°$ N. and $48\frac{1}{2}°$ S.

As already stated, the positions of the Moon and Planets are not marked on the globe because their places change from day to day, but the *Nautical Almanac* gives the necessary information for determining their positions at any time. On page iv of each month the upper and lower meridian passage of the Moon at Greenwich is given in mean time, and on pages v to xii of each month is given the Moon's position for each hour of the day, beginning at noon. The positions of the Planets and the *mean* time of their meridian passage at Greenwich are also given for each day of the year.

If the observer is not on the Greenwich meridian, then the difference of longitude and (in the case of the Moon) the change of its position must be taken into account in determining the local time of transit over his meridian. There are also given the *mean places* of the principal stars in right ascension and declination, and also the *sidereal time* or the right ascension of the *mean* Sun at *mean* noon on page ii of each month.

Problem 16.—(1) Find the Moon's meridian altitude at Greenwich on 8th March 1911.

The Moon's meridian passage on 8th March is 6 h. 49 m. (page iv), and its R.A. and Dec. at 6 h. 49 m. are 5 h. 51 m. and 27° 9′ N. respectively (page vi). To find the Moon's position on the globe, look on the Equator for R.A. 5 h. 51 m. and, having rectified the globe, bring this mark to the meridian circle and read off on this circle 27° 9′ N. This is the Moon's position at 6 h. 49 m. Count the number of degrees from this point to the horizon, and the altitude is 69° 39′.

(2) Find the Moon's meridian altitude on the 21st April 1912 in latitude 56° N., longitude 13 m. W.

Answer.—Altitude 62° 4′.

Problem 17.—(1) Find the meridian altitude of the planet Mars, and also its time of rising and setting at Edinburgh on the 16th November 1911.

The R.A. and Dec. of Mars on the 16th November are (*N.A.*) 4 h. 12 m. and 21° 55′ N. respectively. Its meridian passage at Greenwich is 12 h. 31 m. (morning of the 17th), and therefore 12 h. 31 m. + 13 m. (long.) = 12 h. 44 m. is the time of meridian passage at Edinburgh. Mark Mars' position on the globe by Problem 16. Rectify the globe, and bring Mars' place to the meridian. Its meridian altitude is 55° 58′. Set the hour-circle to 12 h. 44 m., and turn the globe until the planet's place is on the horizon. The hour-circle reads 4 h. 15 m. P.M., the time of rising, and 9 h. 17 m. A.M. (17th), the time of setting.

(2) Find the meridian altitude and time of rising and setting of the planet Saturn at Edinburgh on the 1st December 1911.

Answer.—Meridian altitude, 48°.
Time of rising, 2 h. 57 m. P.M.
Time of setting, 5 h. 59 m. A.M. (2nd December)

Problem 18.—(1) Find the difference in *sidereal* time between the times of crossing of the planets Saturn and Mars over the meridian of Greenwich on 25th November 1911.

The R.A. of Saturn on the 25th November is 2 h. 55 m. (*N.A.*), the R.A. of Mars on the 25th November is 3 h.

57 m. (*N.A.*); therefore the difference in sidereal time is 1 h. 2 m.

(2) Find the difference in *local sidereal* time between the times of crossing of the planets Venus and Jupiter over the meridian of Glasgow on the 3rd December 1912.

Answer.—1 h. 52 m.

Problem 19.—(1) Find the mean time when Sirius is on the meridian of Greenwich on the 6th January 1911.

The sidereal time at mean noon of 6th January is 19 h. (*N.A.*, page ii., of December), and the R.A. of Sirius is 6 h. 41 m. (*N.A.*). The difference of these times is 11 h. 41 m., therefore Sirius is on the meridian of Greenwich 11 h. 41 m. past noon, that is, 11 h. 41 m. P.M.

Note.—This difference (11 h. 41 m.) is *sidereal* not *mean* time hours, etc., but is sufficiently accurate for ordinary purposes as the error is less than 2 minutes.

(2) Find the G.M.T. when Algol (β Persei) is on the meridian of Greenwich on the 4th February 1912.

Answer.—Time, 6 h. 9 m. P.M.

Problem 20.—(1) Find in G.M.T. when Aldebaran (α Tauri) (1) rises, (2) souths, and (3) sets at Edinburgh on the 21st February 1911.

The sidereal time at mean noon at Greenwich on 21st February is 22 h. 1 m., therefore the local sidereal time at Edinburgh is 13 minutes less, namely, 21 h. 48 m. at mean noon. The R.A. of Aldebaran is 4 h 31 m. From 21 h. 48 m. to 4 h. 31 m. is 6 h. 43 m., therefore the star *souths* at 6 h. 43 m. P.M. Rectify the globe, and bring the star's position to the eastern horizon. The R.A. (on the Equator) at the meridian circle now reads 20 h. 50 m., but the R.A. at mean noon was 21 h. 48 m., therefore the star was on the eastern horizon 58 minutes before noon, that is, it *rose* at 11 h. 2 m. A.M. The interval of time between the rising and southing, namely, between 11 h. 2 m. and 6 h. 43 m. = 7 h. 41 m., is called the star's semi-diurnal arc, therefore 6 h. 43 m. + 7 h. 41 m. = 14 h. 24 m., or 2 h. 24 m. A.M. (22nd February) is the time of *setting* of Aldebaran.

(2) Find the G.M.T. of transit of (1) Vega (α Lyræ) and (2) Markab (α Pegasi) over the meridian of Greenwich on the 1st and 31st October 1911.

Answer.—Time of transit—

	1st October.	31st October.
α Lyræ,	5 h. 56 m. P.M.	3 h. 59 m. P.M.
α Pegasi,	10 h. 22 m. P.M.	8 h. 24 m. P.M.

(3) Find the G.M.T. of transit of (1) 61 Cygni, and (2) Fomalhaut (α Piscis Aust.) over the meridian of Glasgow (long. 17 m. 10 s. W.) on the 1st and 31st October 1911.

Answer.—Time of transit—

	1st October.	31st October.
61 Cygni,	8 h. 42 m. P.M.	6 h. 44 m. P.M.
α Piscis Aust.,	10 h. 32 m. P.M.	8 h. 34 m. P.M.

Problem 21.—To find in what direction and at what time an observer must look for a newly discovered comet.

(1) The position of Beljawsky's Comet, discovered on the 29th September 1911, was given on the 2nd October as R.A. 11 h. 14 m. and Dec. 10° 23′ N.: find when, and in what direction, to look for it on that date at Greenwich.

Rectify the globe, and mark the comet's position on the globe (Problem 16). The sidereal time at noon of 1st October is (*N.A.*) 12 h. 36 m. Bring 12 h. 36 m. (on the Equator) to the meridian and turn the globe westward until the comet's position appears on the eastern horizon, and the R.A. at the meridian now reads 4 h. 22 m. From 12 h. 36 m. to 4 h. 22 m. is 15 h. 46 m., from noon of 1st October, that is, 3 h. 46 m. A.M. (2nd October), or time of rising, and the direction on the horizon circle is 15° to the north of east.

(2) The position of Brook's Comet (1911 c) was given as R.A. 12 h. 36 m. and Dec. 12° 10′ N. on the 23rd October 1911: find when and where to look for it in lat. 56° N. and long. 13 m. W. on that date.

Answer.—Time of rising, 3 h. 44 m. A.M.;
Direction, E.NE. (nearly).

Problem 22.—Given the altitude of a known star, the day of the month, and the latitude: to find the hour of the night.

At Greenwich, on the 10th March 1912, the altitude of Arcturus (α Boötes) was found to be 35°: find the time of the night.

Rectify the globe and quadrant. Bring 23 h. 11 m. (the

sidereal time at noon) to the meridian. Turn the globe westward until the star reads 35° altitude on the quadrant, and the R.A. at the meridian now reads 10 h. 12 m. From 23 h. 11 m. to 10 h. 12 m. is 11 h. 1 m., therefore the time is 11 h. 1 m. P.M.

Problem 23.—Given the meridian altitude of any star: to find the latitude.

(1) The meridian altitude of Spica (α Virginis), Dec. 10° 42′ S., was found to be 23° 18′: find the latitude.

23° 18′ + 10° 42′ = 34° is equal to the co-latitude of the place, therefore 90° − 34° = 56° N. is the latitude.

(2) The meridian altitude of Regulus (α Leonis), Dec. 12° 24′ N., was found to be 42° 24′: find the latitude.

42° 24′ − 12° 24′ = 30° is equal to the co-latitude, therefore 90° − 30° = 60° N. is the latitude.

Note.—When the star is known its declination is readily obtained. Bring the star to the meridian, and read off on the meridian circle the number of degrees north or south of the Equator.

Problem 24.—To find the appearance of the heavens in any latitude at any time during the year.

Find the appearance of the heavens at Liverpool (lat. 53° 24′ N., long. 12 m. 17 s. W.) at 9 P.M. on the 7th December 1911.

The sidereal time at mean noon at Greenwich on 7th December is 17 h. 0 m. 33 s., and therefore it is 16 h. 48 m. 16 s. at Liverpool: therefore the sidereal time at 9 P.M. is 1 h. 48 m. 16 s. Rectify the globe, bring R.A. 1 h. 48 m. to the meridian, and all above the horizon ring shows the appearance of the heavens at 9 P.M.

The Constellations.

In the South are	Cetus, Aries and Pisces.
In the South-East are	Taurus and Orion.
In the East are	Gemini, Auriga, Cancer.
In the North-East are	Leo, Lynx.
In the North are	Ursa Major, Draco.
In the North-West are	Draco, Hercules, Lyra.
In the West are	Cygnus, Aquila, Delphinus.
In the South-West are	Aquarius, Pegasus, Pisces.

In and around the zenith are Andromeda, Perseus, Camelopardalis, Cassiopeia, Cepheus, Ursa Minor.

The planet Mars is in the south-east, close to the Pleiades, and Saturn is in Taurus a little to the east of south. The Moon is in the east, close to Castor and Pollux, and about 32° above the horizon.

Problem 25.—Find the appearance of the heavens at Edinburgh (lat. 55° 57′ N., long. 12 m. 43 s. W.) at 10 P.M. on the 12th March 1912.

The sidereal time at mean noon on the 12th March is 23 h. 19 m. 3 s. at Greenwich, therefore the local sidereal time at Edinburgh at mean noon will be 23 h. 19 m. 3 s. − 12 m. 43 s. = 23 h. 6 m. 20 s., and 10 hours after this, is 9 h. 6 m. 20 s. of R.A. Rectify the globe, bring R.A. 9 h. 6 m. (on the Equator) to the meridian ring, and all above the horizon shows the appearance of the heavens at 10 P.M.

The Constellations.

In the South are	Cancer, Leo, Hydra, Sextans.
In the South-East are	Virgo, Coma Berenices, Crater, Corvus.
In the East are	Canes Venatici, Boötes.
In the North-East are	Corona Borealis, Hercules, Serpens.
In the North are	Draco, Ursa Minor, Lyra, Cygnus, Cepheus, Lacerta.
In the North-West are	Cassiopeia, Andromeda, Pisces, Triangula.
In the West are	Perseus, Aries, Taurus, Auriga.
In the South-West are	Gemini, Orion, Lepus, Canis Minor, Canis Major, Monoceros.
In and near the Zenith are	Lynx, Camelopardalis, Ursa Major, Leo Minor.

The planet Mars is in the west between β and ζ Tauri (the horns of The Bull), while Saturn is to the north of west, and nearly under the Pleiades.

Problem 26.—To construct a horizontal sun-dial by the aid of the globe for any latitude.

The Celestial Globe, when rectified to the latitude of the place, may be taken to represent a horizontal sun-dial, its axis serving as the style, and the horizon plate as the outer rim of the dial face. The intersections of the meridian ring with this

plate fix the noon line, and any other graduation may be determined by reading from the plate the number of degrees between the north point and the foot of the hour-circle corresponding to the given time.

To illustrate this, take a sheet of paper and describe two concentric circles of 6-inch and 8-inch radii. Cut out neatly the 2-inch ring and place it on the horizon plate of a 12-inch globe. Rectify the globe to the latitude of the place, and bring an hour-circle to the meridian ring. Put dots on the inner edge of the paper ring, where the hour-circles cut the horizon plate, putting a distinctive mark at the north horizon point. Replace the paper ring, and draw lines from the centre of the circle to the dots, and these form the hour-lines of the dial. Mark the north point XII., and XI., X., etc., towards the west, and I., II., etc., towards the east. This diagram can be transferred to the metal dial-plate.

In the centre fix the style inclined towards the north, or XII., at an angle to the dial face equal to the latitude of the place, and of length sufficient to throw its shortest shadow out to the circumference. Place the dial-plate horizontal, and, with the style true north and south, this constitutes a horizontal dial.

The following table gives the hour-angles for every half-hour, measured on the horizon ring from the north point in latitude 54½° N.

TABLE OF HOUR-ANGLES.

Hours.	*Hour-Angles.*
XII	0° 0′
XI. 30 and XII. 30	6° 7′
XI ,, I	12° 18′
X. 30 ,, I. 30	18° 38′
X ,, II	25° 10′
IX. 30 ,, II. 30	32° 0′
IX ,, III	39° 9′
VIII. 30 ,, III. 30	46° 42′
VIII ,, IV	54° 39′
VII. 30 ,, IV. 30	63° 2′
VII ,, V	71° 47′
VI. 30 ,, V. 30	80° 49′
VI	90° 0′

MISCELLANEOUS EXERCISES.

1. What point on the Celestial Sphere has both its right ascension and declination zero?

2. At what points does the Celestial Equator cut the horizon, and what angle does it make with the horizon at these points as seen by an observer in latitude 40°?

3. When the Vernal Equinox (♈) is rising on the eastern horizon, what angle does the Ecliptic make with the horizon at that point for an observer in latitude $51\frac{1}{2}°$? What angle when setting?

4 What are the approximate right ascension and declination of the Sun on 21st March and 22nd September?

5. What is the Sun's meridian altitude on 21st March for an observer in latitude 56° N.?

6. How far is the Sun from the Zenith at noon on 21st March, as seen by an observer in latitude 60°? How far at noon on 21st June?

7. On 21st March, one hour after sunset, whereabouts in the sky would a star be whose right ascension is 7 hours and declination 40° N., the observer being in latitude 40° N.?

8. What are the right ascension and declination of the North Pole of the Ecliptic?

9. The Sun's true meridian altitude on a ship at sea is observed to be 36° 15′; the Sun's declination at the time is 19° 25′ S. What is the ship's latitude?

10. Find the length of the Longest and Shortest day at London and Cape Town.

11. Find how much the Pole must be raised or lowered where the longest day is an hour longer or shorter than it is at the observer's station.

12. What is the lowest latitude where twilight can last all night? Can it do so at New York? at London? at Edinburgh?

13. Given the Moon's declination, find its meridian altitude at a given place.

14. Find the right ascension and declination of Regulus, Sirius, Vega, and Arcturus.

15. If the same nominal hour is kept for dinner, find whether you dine earlier by local or by standard time.

16. Locate the bright planets for a given day, and see how they are placed with regard to bright stars.

17. Identify the stars α, γ, δ, θ, and η in the constellation of Orion.

18. In what latitude must an observer be in order to see the "Southern Cross" when it is just above the horizon on the meridian?

19. Measure the distance in degrees between β and γ Ursæ Minoris, α and β Pegasi, and the "Pointers."

20. What is the approximate sidereal time on the 4th October at 7 A.M. civil reckoning?

Table I.

SIDEREAL TIME AT (LOCAL) MEAN NOON.

Month.	*Day of the Month.*											
	5th.		*10th.*		*15th.*		*20th.*		*25th.*		*30th.*	
	H.	M.	H.	M.	H.	M.	H.	M.	H.	M.	H.	M.
January .	19	0	19	17	19	36	19	56	20	16	20	36
February .	21	0	21	19	21	39	21	58	22	18	...	
March .	22	50	23	9	23	29	23	49	0	8	0	28
April .	0	52	1	12	1	31	1	51	2	11	2	30
May .	2	50	3	10	3	30	3	49	4	9	4	29
June .	4	52	5	12	5	32	5	52	6	11	6	31
July .	6	51	7	10	7	30	7	50	8	9	8	29
August .	8	53	9	13	9	32	9	52	10	12	10	32
September	10	55	11	15	11	34	11	54	12	14	12	34
October .	12	53	13	13	13	33	13	52	14	12	14	32
November	14	56	15	15	15	35	15	55	16	14	16	34
December	16	54	17	14	17	33	17	53	18	13	18	32

Table I.—If *local mean time* is kept, then this Table gives the *local sidereal time* at *local mean noon* for the above dates. The intermediate dates may be got approximately by adding on 4 minutes for each day. For example: Find the sidereal time at local mean noon on 13th May. The sidereal time on 10th May is 3 h. 10 m., and 3 days = 12 minutes to be added, therefore the local sidereal time on 13th May is 3 h. 22 m. But if G.M.T. is kept, then the *local sidereal time* is greater or less than on the above dates, depending on whether the observer is east or west of Greenwich. For example: If the place be 4° W., then the *local sidereal time* at mean noon (G.M.T.) on 13th May will be 16 minutes less, namely, 3 h. 6 m.

Table II.

EQUATION OF TIME.

Date.	Minutes.		Date.	Minutes.		Date.	Minutes.	
	Add.	*Subtr'ct.*		*Add.*	*Subtr'ct.*		*Add.*	*Subtr'ct.*
Jan. 1	4	...	June 4	...	2	Oct. 17	...	14½
„ 4	5	...	„ 9	...	1	„ 20	...	15
„ 6	6	...	„ 14	0	0	„ 27	...	16
„ 8	7	...	„ 19	1	...	„ 28	...	16
„ 10	8	...	„ 24	2	...	„ 29	...	16
„ 13	9	...	„ 29	3	...	„ 31	...	16
„ 16	10	...	July 4	4	...	Nov. 1	...	16
„ 19	11	...	„ 10	5	...	„ 3	...	16
„ 23	12	...	„ 19	6	...	„ 5	...	16
„ 27	13	...	„ 31	6	...	„ 7	...	16
Feb. 3	14	...	Aug. 1	6	...	„ 9	...	16
„ 10	14½	...	„ 2	6	...	„ 16	...	15
„ 26	13	...	„ 11	5	...	„ 19	...	14½
Mar. 3	12	...	„ 16	4	...	„ 21	...	14
„ 7	11	...	„ 21	3	...	„ 24	...	13
„ 11	10	...	„ 25	2	...	„ 27	...	12
„ 15	9	...	„ 28	1	...	„ 30	...	11
„ 18	8	...	Sept. 1	0	0	Dec. 3	...	10
„ 22	7	...	„ 4	...	1	„ 5	...	9
„ 25	6	...	„ 7	...	2	„ 8	...	8
„ 28	5	...	„ 10	...	3	„ 10	...	7
April 1	4	...	„ 13	...	4	„ 12	...	6
„ 4	3	...	„ 15	...	5	„ 14	...	5
„ 7	2	...	„ 18	...	6	„ 16	...	4
„ 11	1	...	„ 21	...	7	„ 18	...	3
„ 15	0	0	„ 24	...	8	„ 20	...	2
„ 20	...	1	„ 27	...	9	„ 22	...	1
„ 25	...	2	„ 30	...	10	„ 24	0	0
„ 30	...	3	Oct. 3	...	11	„ 27	1	...
May 5	...	3	„ 6	...	12	„ 29	2	...
„ 14	...	4	„ 10	...	13	„ 31	3	...
„ 28	...	3	„ 14	...	14			

Table II.—This Table gives the number of minutes to be added to or subtracted from *local apparent time* to give *local mean time*. For example: Find the *local mean time* at *local apparent noon* on 2nd August. From the Table 6 minutes are to be added, therefore the *local mean time* on 2nd August at *local apparent noon* is 12 h. 6 m.

But if G.M.T. is kept, then the difference in longitude must be taken into account. For example: Find the G.M.T. at a place 4° W. on 30th September at *local apparent noon.* From the Table 10 minutes are to be subtracted from *apparent noon*, therefore the G.M.T. is 11 h. 50 m. at *apparent noon* at Greenwich. But the sun is not on the meridian of a place 4° W. till 16 minutes later, that is, at 11 h. 50 m. + 16 m. = 12 h. 6 m. G.M.T.

GREEK ALPHABET.

Α	α	a	Alpha.	Ν	ν	n	Nu.
Β	β	b	Bēta.	Ξ	ξ	x	Xi.
Γ	γ	g	Gamma.	Ο	ο	ŏ	Ŏmīcron.
Δ	δ	d	Delta.	Π	π	p	Pi.
Ε	ϵ	ĕ	Ĕpsīlon.	Ρ	ρ	r	Rho.
Ζ	ζ	z	Zēta.	Σ	σ	s	Sigma.
Η	η	ē	Ēta.	Τ	τ	t	Tau.
Θ	θ	th	Thēta.	Υ	υ	u	Upsīlon.
Ι	ι	i	Iōta.	Φ	φ	ph	Phi.
Κ	κ	k	Kappa.	Χ	χ	ch	Chi.
Λ	λ	l	Lambda.	Ψ	ψ	ps	Psi.
Μ	μ	m	Mu.	Ω	ω	ō	Ōmĕga.

ASTRONOMICAL SYMBOLS.

☉	The Sun.	♀	Venus.	♄	Saturn.
☾	The Moon.	⊕	The Earth.	♅	Uranus.
☿	Mercury.	♂	Mars.	♆	Neptune.
		♃	Jupiter.		

ABBREVIATIONS.

h., m., s.	Hours, minutes, seconds.
° ′ ″	Degrees, minutes, seconds.
N., E , S., W.	North, east, south, west.
G. M.T.	Greenwich Mean Time.
N. A.	*Nautical Almanac.*
R.A.	Right Ascension.
+	Add.
–	Subtract.
=	Equals.
Lat.	Latitude.
Long.	Longitude.
Dec.	Declination.

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